THE PROGRAMS

The Programs

The missions of Solar System Exploration are conducted within several programs, each of which has an annual budget that covers mission development, launch, and operations. The three existing programs are the Outer Planets program, the Mars Surveyor program, and the Discovery program. The first two of these focus on particular scientific objectives, and missions are selected by NASA through the strategic planning process. The next recommended missions for these programs are identified in this document. The Discovery program is a scientifically broad program whose missions are competitively selected; they may complement the missions in the other two programs or they may independently address goals expressed in this Roadmap.

We recommend two critical new elements. The first is a new program of exploration missions called “To Build a Planet”. This will focus on the processes of planet formation and evolution, and will fill crucial gaps in our understanding of the Origins of solar systems and therefore of life itself. Our top priority new mission in this Program is the Comet Nucleus Sample Return. The second new element is a set of investments in facilities and capabilities for handling and analyzing the samples to be returned from Mars. These investments will ensure that the samples can be handled safely and in a manner that the public will understand and support, and will maximize the science return from analysis of these extremely valuable samples. The same facilities and procedures will also be used for future sample returns from throughout the solar system.

Solar System Exploration: Continuing Programs

Outer Planets Program: ***Exploring Organic-Rich Environments***

- Studies the organic-rich environments, prebiotic chemical processes, and possible habitats for life in the outer solar system.
- Europa Orbiter and Pluto/Kuiper Express are in existing strategic plan and are under development for launch in 2003 and 2004
- *Highest priority new missions are identified in this roadmap*

Mars Surveyor Program: ***Bringing Mars to Earth***

- Seeks to understand Mars climate history, evidence of past or present life, and potential for future human exploration
- A long-term program of intensive Mars exploration and sample return; first samples return to Earth in 2008
- *High priority new missions are identified in this roadmap*

Discovery Program: ***Partnerships for Innovation***

- Highly successful program of community-led missions
- Expectation that some high priority strategic objectives will be addressed through competitive Discovery process *(see, e.g., To Build a Planet…)*

Solar System Exploration: Critical New Elements

New

To Build a Planet: *Formation and Evolution of Planetary Environments*

- Studies the processes of planet formation and how they have resulted in the diverse bodies in our solar system today
- Comprises missions which are too demanding or technologically intensive to be conducted under the Discovery program
- *A new program…initial recommended mission set is identified in this roadmap*

New

Mars Sample Handling and Analysis

- A new element to develop new facilities and upgrade existing lab capabilities
- Enables sample processing, curation, and analysis for maximum science value
- Helps to ensure public acceptance of sample return as a safe and valuable mode of exploration

Why "*To Build A Planet...*"?

Current programs do not adequately address Quest 1, "Explain the Formation and Evolution of the Solar System and the Earth Within It"

- *Outer Planets: Exploring Organic-Rich Environments* is focused on Quest 2: Seek the Origin of Life and its Existence Beyond Earth

- *Mars Surveyor: Bringing Mars to Earth* addresses Quest 1 for only a single solar system destination

- *Discovery: Partnerships for Innovation* has contributed mainly to Quest 1, but many essential missions are outside the scope of Discovery due to their complexity and technology requirements

"To Build a Planet…", beginning with Comet Nucleus Sample Return, will achieve the second NASA Guideline in the National Space Policy:
"NASA will undertake ... A long-term program, using innovative new technologies, to obtain *in situ* measurements and sample returns from celestial bodies in the solar system".

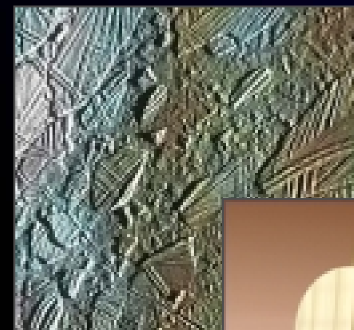
Outer Planets Program: Exploring Organic-Rich Environments

Exploration of the outer solar system, from the early Pioneer and Voyager flybys to today's Galileo mission, have revolutionized our view of the solar system. In part, we have learned that the outer planets and their moons are rich in organic material, that subsurface liquid water may exist in some places, and that prebiotic chemical processes are taking place in some of these environments. The Cassini/Huygens mission, en route now, will extend this exploration by conducting an intensive study of Titan's atmosphere and surface.

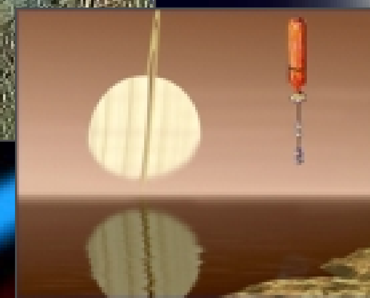
The Outer Planets program was established in the prior Space Science Enterprise Strategic Plan. It is intended to focus on environments in the outer solar system that can provide insight into prebiotic chemistry and possible habitats for life. The first two missions in this program are the Europa Orbiter and the Pluto/Kuiper Express; they are currently under development for launch in 2003 and 2004 respectively.

Following the Europa Orbiter and Pluto/Kuiper Express missions, the highest priority missions are the *Europa Lander, Titan Explorer, and Neptune Orbiter* (not in priority order). These missions will build on the results from the past, present, and upcoming missions and will conduct in-depth analyses of these organic-rich environments. Mission sequence decisions will be based on our continuing scientific discoveries and the progress of our technology programs.

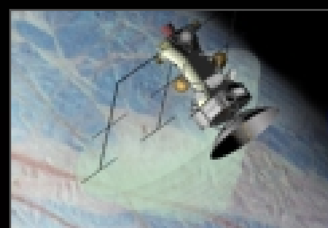
Outer Planets Program: Exploring Organic-Rich Environments



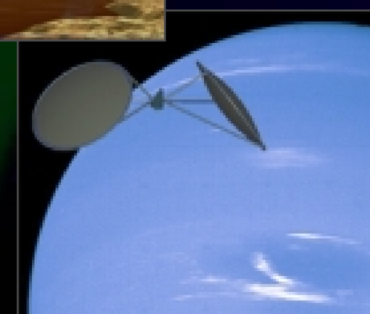
Europa Lander



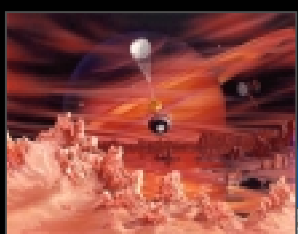
Titan Explorer



Europa Orbiter

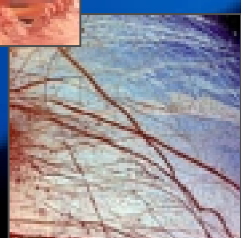


Neptune Orbiter



Cassini/Huygens

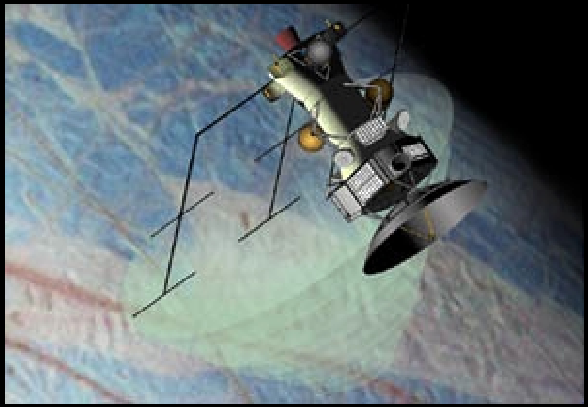
Pluto/Kuiper Express



Galileo-Europa

Exploring Organic-Rich Environments: Current Missions

Europa Orbiter

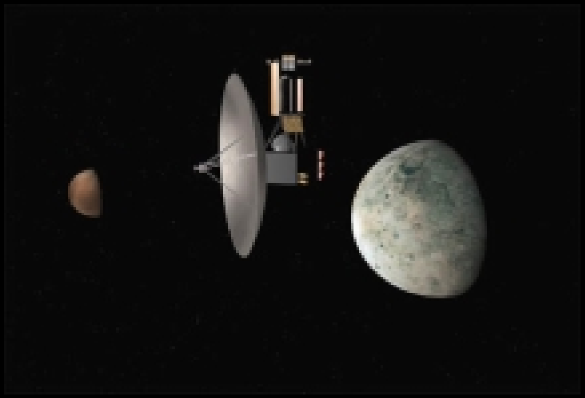


Key Questions:

- **Is there an ocean of liquid water beneath Europa's ice?**
- **Are there places where the ice is thin or where water reaches the surface?**
- **Could the Europa environment support pre-biotic chemical processes?**

Launch:	**Nov 2003**
At Jupiter:	**2006**
At Europa:	**2008**

Pluto-Kuiper Express



Key Questions:

- What are the **origins of Pluto, Triton, and the Kuiper Belt?**
- **What is the surface composition and atmospheric structure of Pluto and Charon?**
- **What is the organic inventory of the far outer solar system?**

Launch:	**Dec 2004**
At Pluto:	**2014**

Exploring Organic-Rich Environments: Europa Lander Mission

Europa is a top scientific priority because of the strong suggestion that liquid water exists (or once existed) beneath its surface ice. Such a subsurface ocean would certainly contain organic material; in fact, the environment may be similar to the deep ocean hydrothermal vents on Earth where life has been detected and may have originated. Evidence of prebiotic chemistry or perhaps even biology may be evident in what appears to be dark fracture-filling material on the planetary surface. The possibility of finding such traces of biotic or prebiotic material lends very high priority to a Europa Lander mission.

The mission's fundamental goal is to land on and/or penetrate into one or more surface sites to access material recently derived from subsurface liquid water. Some specific measurement objectives are to:

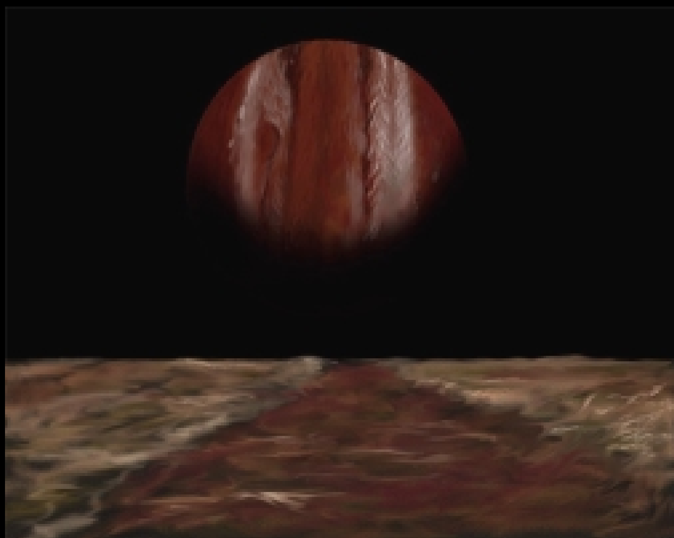
- Characterize the near-surface composition, especially any organic materials, salts, and indicators of high-temperature water-rock interaction;

- Determine the compositional, geophysical, and geological context for the surface sites on a global, regional, and especially local (~5–10 km) scale;

- Search for indications of Europan biology, including chemical or isotopic signatures of non-equilibrium processes.

The Europa Lander mission can be ready for launch by approximately 2008, depending on funding for the critical technologies. This mission will be poised to take advantage of the results and capabilities of the Europa Orbiter mission currently under development. Key technologies include lightweight chemical propulsion for descent to the surface, miniature organic chemistry labs, autonomous landing system, and bioload reduction to ensure protection of the Europa environment and to eliminate the possibility of "false positives" in the search for evidence of life.

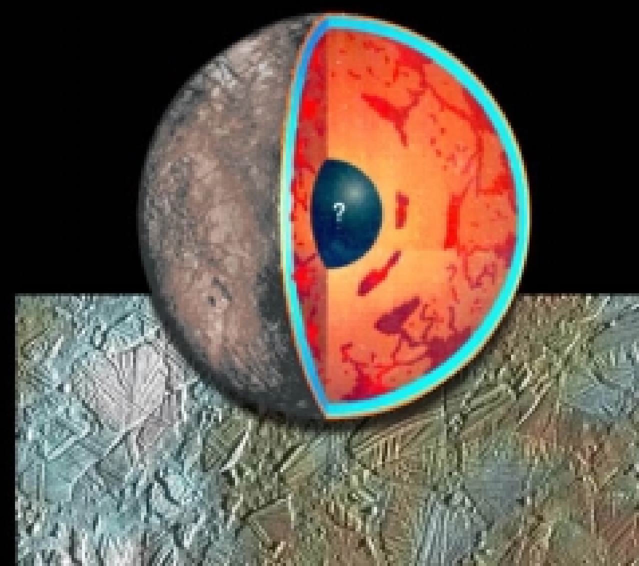
Exploring Organic-Rich Environments: Europa Lander Mission



- ***Critical Questions***
  - What is the age and composition of the Europa surface?
  - What organic chemical processes are taking place?
  - Is there potential access to liquid water?
  - Are there any indications of biological activity?

- Ready for mission start: 2005
- 6-8 year mission duration
- Technology demo of future subsurface access

- ***Key Capabilities***
  - High performance, low mass propulsion for descent
  - Autonomous landing and hazard avoidance
  - Miniature organic chemistry laboratories
  - Sample acquisition & processing
  - Bioload reduction
  - Radiation tolerant components

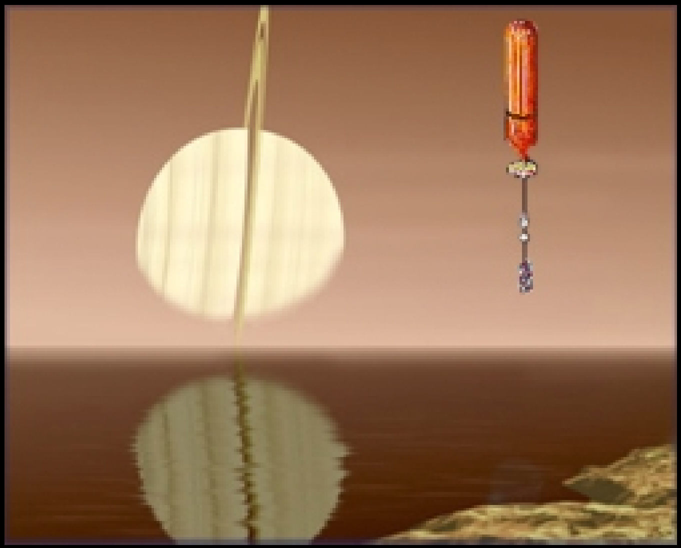


Exploring Organic-Rich Environments: Titan Explorer Mission

The atmosphere of Titan, Saturn's largest satellite, has been known for over 50 years to contain methane. Voyager found Titan's atmosphere to be suitable for the production and retention of prebiotic organic material, and Cassini/Huygens will further explore the atmosphere and its interactions with the surface. The atmospheric chemistry of Titan is thought to be similar to that of the early Earth, before life took hold, and thus a detailed study of Titan's atmosphere provides a unique opportunity to look back to a time and a set of chemical conditions that we can no longer observe on Earth. This will provide an important bridge between the study of life's chemical building blocks and the study of more evolved environments such as Mars and Earth, and may be a key to an ultimate understanding of the origin of life.

The Titan Explorer will measure the distribution and composition of organic material on the surface and in the atmosphere of Titan, and will study the prebiotic chemical processes that are taking place in the atmosphere. The mission will utilize a mobile atmospheric platform such as a balloon or aircraft, a lander or mobile surface station, or some combination of these. A sophisticated miniature organic chemistry lab will enable detailed *in situ* analysis of chemical processes over time and at a variety of locations. Other key technologies such as aerocapture at Saturn and/or Titan will be required, and investments are beginning now to establish launch readiness near the end of the next decade. This will position NASA and the nation to take the next critical step following the exciting discoveries we anticipate from the Cassini/Huygens mission.

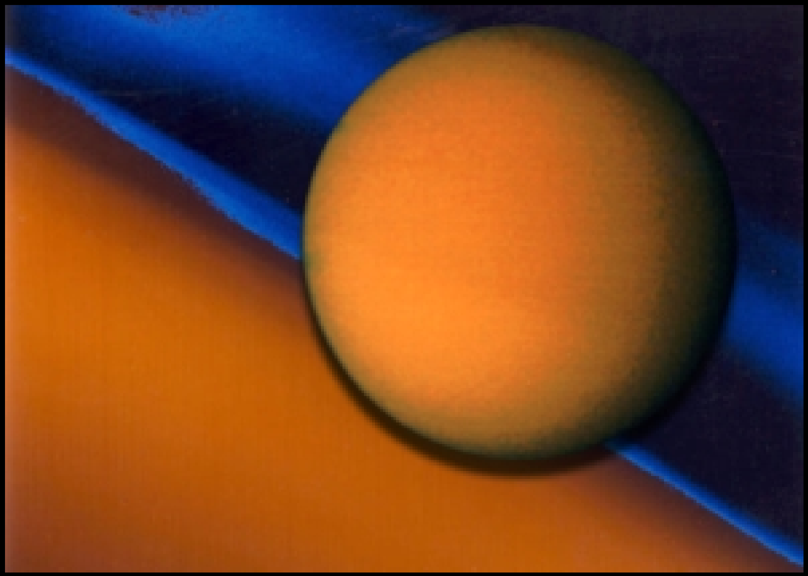
Exploring Organic-Rich Environments: Titan Explorer Mission



- ***Critical Questions***
  - What prebiotic chemistry is taking place at Titan and what can it tell us about the primordial Earth…and the origin of life?
  - What is the composition of Titan's surface and how does it interact with the atmosphere?
  - How has Titan evolved over its history?

- Ready for mission start: 2006-2007
- Atmospheric and surface measurements
- Balloon or aircraft for mobility

- ***Key Capabilities***
  - Aerial platform or surface rover
  - Aerocapture at Titan
  - Miniature *in situ* chemistry lab
  - Sample acquisition
  - Bioload reduction



Exploring Organic-Rich Environments: Neptune Orbiter Mission

The Neptune Orbiter mission will conduct an in-depth examination of the most distant planetary system in our solar system. It will examine and monitor over time Neptune's atmosphere, magnetic field and magnetosphere, and unusual ring and satellite system. The mission will also focus on Triton, Neptune’s large, active, Pluto-like satellite.

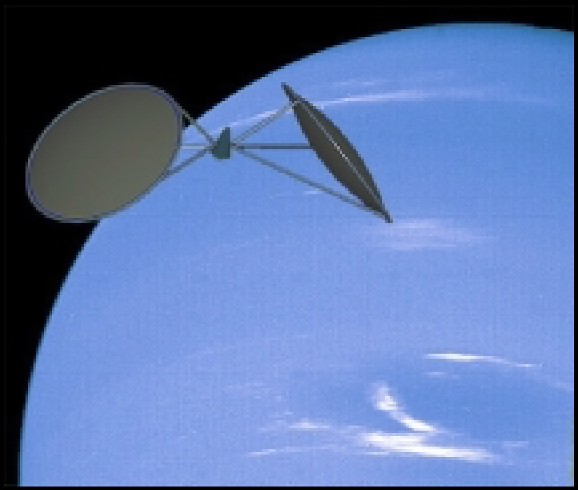
Neptune itself serves as a local analog of the kinds of extrasolar planets that are likely to be discovered soon. In the rapidly developing search for extrasolar giant planets, many Jupiter-class and some Saturn-class planets and brown dwarfs have been detected. It is likely that technological improvements will soon enable detection of planets with masses on the order of 0.1 Jupiter mass. In our solar system, this class of planet is represented by the distinctly different giant planets Uranus and Neptune, about which much less is known than about Jupiter and Saturn.

Moreover, Neptune's zonal winds, its clearly identifiable and oscillating storm systems, and its internal heat source offer the chance to study and compare among the planets the energetics of atmospheric meteorology, which are surprisingly strong at Neptune. The unusual configuration of its magnetic field -- extremely tilted and so offset from the planet's center that it must have its origin in the outer watery envelope of the planet -- make it a local analog for a class of early main sequence stars known as “oblique rotators”.

Triton was shown by Voyager to be a unique, organic-rich object with a very thin atmosphere and signs of internal activity. There is evidence that it is a Kuiper object that was captured by Neptune. The Neptune Orbiter will provide the unprecedented opportunity for repeated close flybys of Triton for detailed mapping and chemical analysis.

The Neptune Orbiter will constitute the most distant robotic “permanent” outpost in the solar system and an observational platform positioned to study and monitor over time the coldest and most alien environment we have visited thus far.

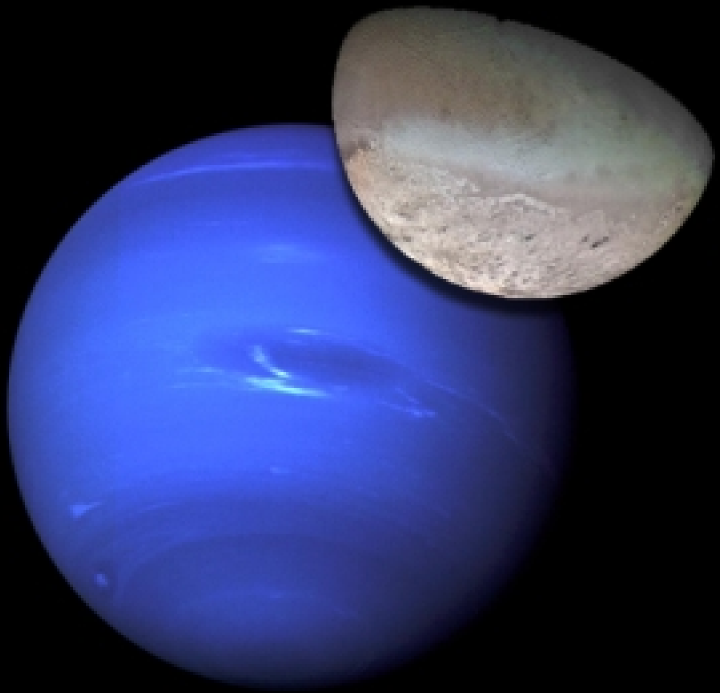
Exploring Organic-Rich Environments: Neptune Orbiter Mission



- ***Critical Questions***
  - What is Neptune's atmospheric structure and chemistry? What is the structure and behavior of its magnetosphere?
  - What are Triton's physical properties? Is it a captured Kuiper object? What is the nature of any organic material on its surface?
  - What are the dynamics of the rings and satellites?

- Ready for mission start: 2006-2007
- 10 year flight to Neptune, 2-4 year orbital tour
- Multiple flybys of Triton and sampling of upper atmosphere

- ***Key Capabilities***
  - Aerocapture
  - Advanced telecommunications system
  - High-power solar electric propulsion
  - Autonomous spacecraft operations
  - Temperature tolerant electronics

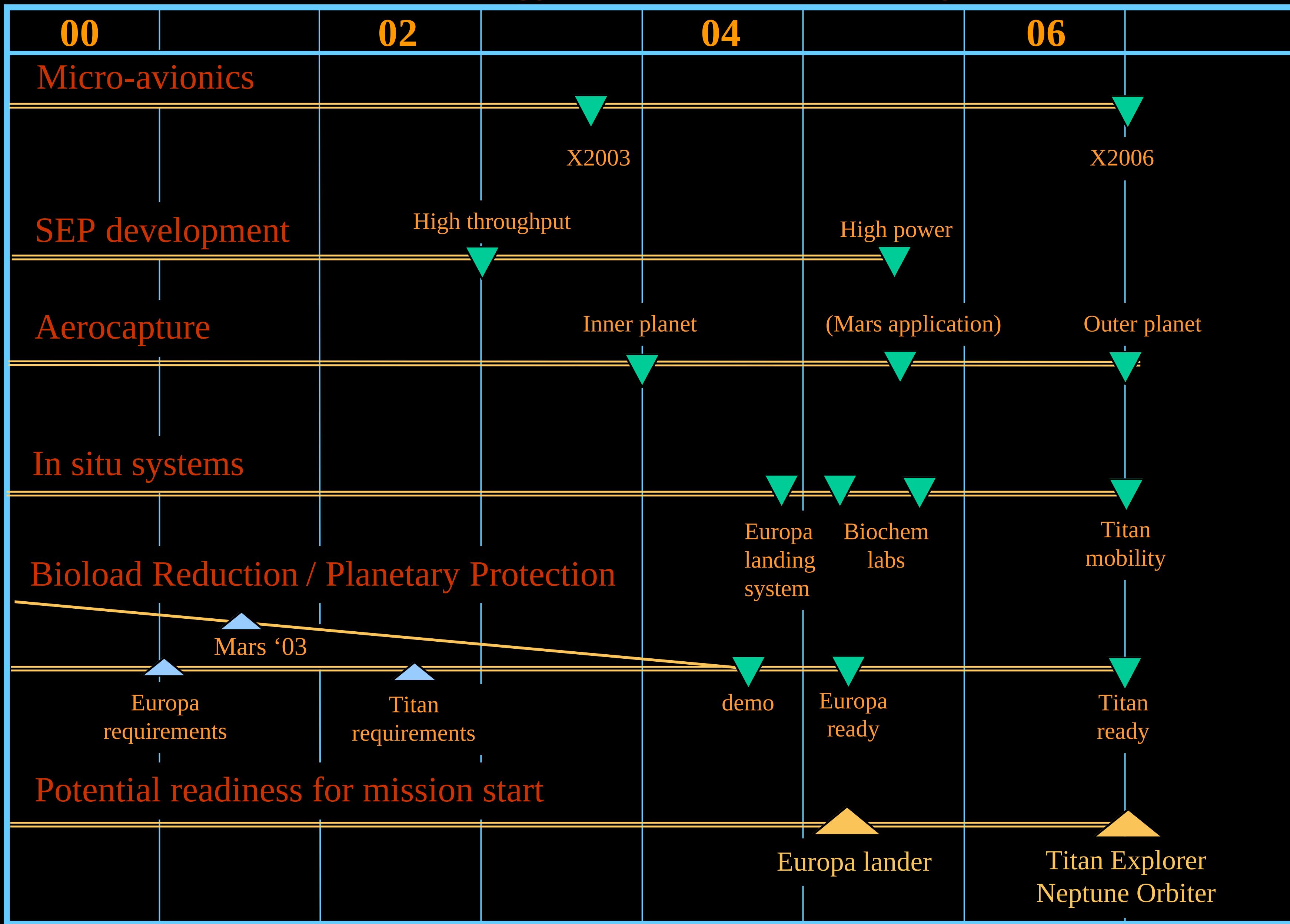


Outer Planets Program: Technology Readiness Summary

Detailed analyses and trade studies have been conducted to establish the feasibility and technology priorities for the recommended missions of the Outer Planets program. These build on the foundation of technologies being developed for the current missions, Europa Orbiter and Pluto/Kuiper Express. Significant investments which are being made now in micro-avionics, advanced computing systems, radiation tolerance, and autonomy, form the core of the deep space systems required for these challenging, long-duration missions.

Highly capable, autonomous micro-avionics systems are a key to all future outer planet missions. Avionics technologies projected for readiness in 2003 can support the Europa Lander, while further advances are required for the Titan Explorer and Neptune Orbiter with readiness projected for 2006. The Titan and Neptune missions also rely on advanced high-power solar electric propulsion (SEP) and aerocapture to enable missions of sufficiently low mass and flight time. Investments are being made now in both of these areas, and technology readiness in 2006 is feasible. Europa Lander readiness will be driven by progress in bioload reduction (some of which will leverage developments for Mars Sample Return) and by the capability to land softly on a massive airless body, which requires advances in chemical propulsion efficiency and miniaturization. Potential mission start dates can be derived from analysis of the individual mission technology needs and on reasonable projections of technology funding. The Outer Planets program planning and mission sequence decisions will be based on a logical progression of technology investments, to minimize the overall cost to NASA.

Outer Planets Program: Technology Readiness Summary

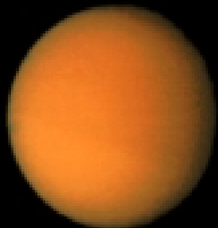


Exploring Organic-Rich Environments: Future Concepts

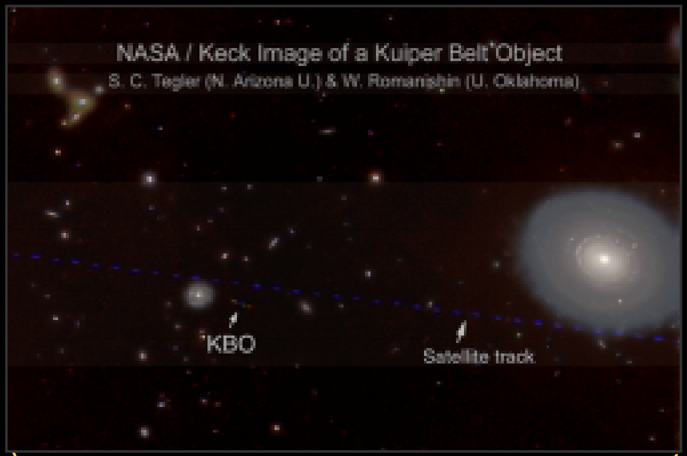
The continued exploration of organic-rich environments will build on the discoveries and capabilities of the nearer-term missions. Of high priority will be further intensive exploration of environments such as Titan, Europa, and the giant planets, possibly including sample return. If Europa is found to have an accessible liquid layer, a Europa ocean science station will one day allow a detailed chemical analysis and search for evidence of extant life in that environment; if discoveries warrant, Europa could eventually become the focus of a dedicated exploration program not unlike Mars Surveyor. Continued development of an integrated picture of life's origins in the solar system will also motivate more intensive studies of the Kuiper objects and other primordial bodies at the edge of the solar system. Triton, as the most accessible member of this class of distant objects, and a site of known geological - and possibly chemical - activity, may even be a target for landing and sample return.   New technologies such as solar sails, highly autonomous self-repairing spacecraft, advanced power generation, and advanced communications will enable all of these missions and will ultimately extend our reach beyond the boundaries of our solar system.

Exploring Organic-Rich Environments: Future Concepts

Triton Lander



Outer Planet Satellite Sample Returns



The Kuiper Belt and Interstellar Exploration

Europa Ocean Science Station